THE EFFECT OF CERTAIN CULTURAL PRACTICES ON THE DEVELOPMENT OF ROOT-ROT DISEASE IN WINTER WHEAT

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CHAPTER I

INTRODUCTION

Dry-land-foot-rot of wheat, Triticum aestivum L., has been a prominant problem in the major wheat and barley growing areas of the United States, Canada and other parts of the world. Many aspects of the disease have been studied by numerous researchers since the recognition of the principal causal pathogen, Helminthosporium sativum P., K., & B., by Pammel, King and Bakke in 1910 (51). The perfect stage of H. sativum, Cochliobolus sativus (Ito & Kurib)Drechsl, ex Dastur, has been demonstrated (69), but the name of the imperfect stage, H. sativum, is much more commonly used by most plant pathologists and will be used here. Dry-land-foot-rot disease of wheat is also known by or confused with several other common names: crown-rot and root-rot. The pathogen is also known to cause black joint, spot blotch, leaf spot, seedling blight, kernel smudge, black point and spike and seed blight depending on the location of the infection and disease development on or in the various parts of wheat, barley or rye plants (5, 31, 42, 74).

The source of inoculum of H. sativum for these various diseases has been extensively studied. Wheat culture systems, where continuous cropping is practiced and stubble-mulch tillage is widely used, promote survival of conidia in soil and plant debris and mycelial survival in infested plant residue (8, 11, 18, 61). Inoculum may also come from infected seeds as a result of head blight the previous season (66).

The conidiospores of H. sativum have a greater longevity at the surface of the soil than when the infested material is incorporated in the soil, perhaps due to a lower relative humidity (36). The fungus develops well at warmer temperatures and exhibits more activity in host plants subjected to moisture stress (45, 48).

Disease ratings have usually been based on measurements of diseased roots, samplings of basal portions of plant stems or yield comparisons made in an "end-of-season" sampling process. More recently, some researchers have developed techniques for detecting the disease and its progress based on lesions on infected hypocotyls or coleoptiles (4, 35, 71). In the studies reported here, the coleoptile, the hypocotyl and the basal leaf have been the major plant parts used in assaying disease levels.

Control measures such as late planting of winter wheat, chemical seed treatment, and resistant varieties have been suggested by various authors since the study of the disease began (5, 20, 26, 48, 55, 63). Such programs, singly or in various combinations, have been observed to reduce the incidence of the disease significantly but do not control it completely.

The requisites of a successful seed treatment chemical are many, which necessitates extensive screening and testing before a product can be recommended for control programs (62, 70). Initial screening programs have been, and are being, carried-out by many manufacturers (43). Following this evaluation the selected chemicals must be evaluated in the field for effectiveness and for economical rates and methods of application. Such tests are often carried out by plant pathologists doing research on seedling and root diseases. Such a study forms a portion of the work

reported here.

Dry-land-foot-rot disease of wheat is complicated by the presence of Fusarium sp. wherever the disease is found. The major species seems to be Fusarium culmorum which also may cause root-rot of wheat. The disease caused by Fusarium sp. has been extensively studied by numerous workers since at least 1923 (24, 58, 59, 72). In the Pacific Northwest the disease causes losses in wheat and other cereals of 50% or more (58).

F. culmorum can be readily isolated from the basal portions of stems or straw of wheat from fields where root-rot had been observed (10, 22, 50, 53, 58, 72). The fungus is widely present in the soil (11) and survives as a saprophyte in soil and plant refuse in infested fields (50, 53, 72). Chlamydospores of F. culmorum isolated from soil and from buried straw (72) were equally as pathogenic on wheat seedlings as were isolates recovered directly from infected plants.

Much work has been done on the practice of minimum tillage systems (stubble mulch) using either mechanical tillers, herbicides or combinations of the two (6, 9, 30, 46, 47, 73, 75). The principal objective of such investigations has been to improve soil conservation techniques by preventing wind and water erosion, conserving soil moisture, controling weeds, and minimizing mechanical tillage. With few exceptions (39), these studies have not considered the relationship of tillage methods to the dry-land-foot-rot disease, although H. sativum has been noted to be more prevalent in trashy fields (5).

Therefore, the major thrust of this investigation was to study the influence of levels of tillage on the development of dry-land-foot-rot or root rot as measured by initial stand, plant development, and the presence of incitant organisms in the initial structures of the wheat plant. The effect of a chemical seed treatment was also considered.

CHAPTER II

LITERATURE REVIEW

Many workers have confirmed that the conidiospores of H. sativum can endure extreme environmental conditions and retain the ability to germinate and attack the host when conditions are favorable to its development. Ledingham and Chinn (37) developed a flotation method for detection of conidiospores of H. sativum and surveyed conidial populations in field soils. They found a direct relationship between the spore population and disease incidence on seedlings and mature plants. Simmonds et al. (61), in 1950, reported that H. sativum could over-winter in the wheat-producing regions of Western Canada and that the spores of this pathogen were found extensively in the soil. They conculded that conidiospores of H. sativum in, or on, the surface soil or produced on stubble are an initial source of inoculum of root-rot of wheat. They have also suggested that this inoculum retains viability for a long period. Chinn and Ledingham (16), in 1958, found that spores can remain dormant in soils up to 2 years under field conditions. Consequently, it is not surprising that they also found that spore counts from summer-fallowed soil and from fields planted to wheat or barley did not differ significantly (18, 19).

Boosalis (7) made an extensive review of the literature in 1960 concerning the presence of spores of H. sativum in the soil and also was able to show the extensive presence of conidiospores in the soil of

wheat fields in Nebraska.

Later Boosalis (8), in 1962, reported that numbers of viable spores of H. sativum diminish very sharply after 3-4 months in heavy soil in Southern Nebraska, but more than 60% of these conidiospores remain viable after 16-17 months in fine sandy loam soils of the same area. Bekele (4), in 1975, found spores of H. sativum in wheat field soils near Lahoma, Oklahoma where the experiments reported here were conducted.

Butler (11, 12, 13) found H. sativum within infected wheat straw tissue and showed that the fungus remained viable in the soil for an extended period.

Ledingham (36), studied the longevity of spores of Cochliobolus sativus grown on straw at various temperatures and relative humidities. He concluded that spores of C. sativus have a better chance of survival on the surface of the soil than if the infected straw is incorporated in ths soil.

Slykhuis et al. (63) experimented with planting winter wheat at weekly intervals beginning August 11 to November 3. They found the earliest sown wheat was highly damaged by H. sativum while damage was successively less in wheat sown later. The fact that spores of H. sativum germinate and grow well at high temperatures, a condition detrimental to the host, has been shown by several workers (5, 20, 24, 45, 48), which certainly is evidence for the success of later planting of winter wheat and early planting of spring wheat.

A number of workers have shown the effectiveness of date of planting in the reduction of incidence of plant disease. Christensen (20), as early at 1922, determined that H. sativum lacks the ability to thrive well at temperatures of 40 to 50F and recommended sowing spring wheat

early in the season. Later Porter and Layton (52) also suggested early planting of spring wheat as a method of reducing the damage caused by foot and root rots. Boewe (5), in 1939, advised late fall seeding for winter wheat and early seeding for spring wheat. Sprague (65) also recommended a late fall planting date as part of a series of cultural practices aimed at the control of root-rot disease in wheat.

Dosdall (24), in 1923, studied the effect of temperature upon the growth of H. sativum in the laboratory. She found the optimum temperature to be 24 to 28C with minima and maxima of 0 to 2 and 35 to 39C, respectively. She also concluded that H. sativum induces severe disease injury in situations unfavorable to the development of the host.

McKinney (48) also, in 1923, studied the influence of soil temperature and moisture on infection of wheat seedlings by H. sativum. His results indicated that optimum plant development occurred at temperatures between 20 and 24C and that temperatures of 16 to 20C favored root development as compared to foliage growth. He found that the optimum temperature for host growth was not the same as that for the parasite which was found to be 24 to 28C. Disease development however, was favored by a temperature suitable to neither the host nor the parasite, but at 28 to 32C. While Mckinney (48) found that relatively high moisture favored the Helminthosporium disease of wheat, and that the optimum temperature for disease development remained constant at all soil moistures, numerous workers have stressed the importance of predisposing factors on wheat plants exposed to H. sativum. Fenster (26) reported that, in Western Nebraska, the incidence of H. sativum can be checked or reduced through later seeding dates. He also suggested that if adequate moisture became available during fall, early

planting may result in lush growth, which in turn produces severe water stress on the plants if moisture later becomes limiting. He found that root rot caused by H. sativum thrived at the expense of plants weakened due to water stress.

Although the pathogenic nature of H. sativum has been well established, certain other fungi have been isolated from root or foot-rot diseased plants.

Dosdall (24) compared the infectivity of isolates of both H. sativum and F. culmorum on Marquis wheat and Lion barley cultivars and was able to reproduce foot-rot disease with both fungi. Her isolate of F. culmorum came from scabby wheat.

Samuel and Greaney (58), in 1937, isolated F. culmorum from surface sterilized roots and crowns of apparently healthy wheat plants which showed no disease symptoms. The authors assayed plant samples from 3 fields in different localities at fortnightly intervals between heading and harvest. The percentage of F. culmorum isolated increased with advance of the season, and reached maximum in isolates from wheat stubble after harvest. However, Cook and Bruehl (22), in 1968, made it clear that the prominence of F. culmorum on wheat straw under field conditions in the Pacific Northwest was largely from parasitism of the crowns and bases of culms during plant growth, and not from saprophytic colonization of straw residue after harvest.

Sadasivan (53), in 1939, reported that isolates of F. culmorum obtained as saprophytes on wheat straw were shown to be pathogenic to wheat seedlings. These results were later confirmed by Walker (72) who isolated F. culmorum from buried straw and showed that such isolates were just as pathogenic to wheat seedlings as those isolates from

diseased but living plants.

Shen (59) reported the inability of F. culmorum to spread along either the inside or outside of the seminal roots and was therefore limited in its parasitism. He said, however, that, "injury to the cereal plant whether by drought, soil acidity, excess of soluble salts or mechanical damage to the seed predisposes the plant to Fusarium infection". This view is supported by Machacek and Greaney (41) who showed that mechanical injury of the seed predisposing seedlings to Fusarium infection.

Malalasekera and Colhoun (44), in 1968, found F. culmorum as a causal agent in most pre-emergence death of wheat seedlings in dry soil. They stated that wheat seedlings had a high percentage of pre-emergence death in dry soils as compared with wet soils and attributed this to the extended time elapsed between sowing and emergence of seedling above ground. Soaking wheat seeds in water for 1-12 hours prior to planting permitted more rapid emergence and reduced the incidence of disease.

Cook (21), in 1968, reported that Fusarium root-rot is a common disease of wheat and other cereals in the Pacific Northwest. He indicated that losses up to 50% are common in some fields. Throughout that cereal growing area 90-95% of the isolates were F. culmorum type and only traces of F. roseum and F. graminearum were found.

However, Nyvall (50), in 1969, found 67 to 87% of his isolates were F. oxysporum, 6 to 10% F. solani, and only 2% were F. culmorum. He also found that after the plants matured, the percentage of F. culmorum rose to as much as 59% of the total isolates, indicating the saprophytic ability of this organism. Bruehl and Lai (10) recovered

F. culmorum in great numbers both from buried straw and infected basal portions of diseased wheat plants.

Walker (72), in 1941, made an extensive study of the colonization of wheat straw buried in soil. He concluded that F. culmorum dominated in the early stage and Penicillium spp. dominated in later stages of straw colonization.

The lack of competitive ability of H. sativum has been studied by many workers. Greaney and Machacek (27), in 1935, found that the pathogenicity of H. sativum was reduced in the presence of Trichothecium (Cephalothecium) roseum Corda.

Butler (11) compared 4 foot-rot pathogens, H. sativum, Ophiobolus graminis, Curvularia ramosa and F. culmorum in their ability to colonize wheat straw. He found that F. culmorum and C. ramosa were strong colonizers in competition with natural microflora of the soil, while H. sativum and O. graminis were weak competitors.

Ledingham (34) investigated the interaction of H. sativum and F. culmorum on potato-dextrose agar in the laboratory. To determine differences between these 2 fungi he used a radial growth rate measurement. When these 2 organisms were placed at opposite ends of a Petri dish he found the radial growth of H. sativum was sharply checked by the growth of F. culmorum.

Young (74) studied all possible combinations of 2 of the 3 fungi, H. sativum,and isolates of Fusarium sp. and Penicillium spp. obtained from corn. He found that Fusarium isolate dominated H. sativum and that the Penicillium isolate dominated both of the other fungi on potato-dextrose agar.

In a farming system where continuous cropping is used, as in the

Great Plains area, for the production of small grains, stubble mulch tillage has played an important role in the control of soil erosion. Earlier workers who developed and promoted stubble mulch systems, however, failed to recognize the importance of disease incidence with such a tillage system.

Whitefield et al. (73), in 1949, reported a substantial yield increase with the stubble mulch tillage system over the moldboard plow or the one-way plow tillage system. Zingg and Whitefiled (75) made a 17-year study throughout the Great Plains and the Pacific Northwest. Their summary of stubble mulch experiments indicated that the superior yield under stubble mulch tillage at Amarillo, Texas, was attributed to the conservation of moisture. The importance of disease was not noted, but problems with grassy weeds arose. Under these conditions yield was lowered in the stubble mulch tillage plots. The weed problem on stubble mulch tillage was also encountered by Harper (30), in 1960, and Bond et al. (6), in 1971.

Baker et al. (3), in 1956, conducted chemical summer fallow experiments in 3 areas in Montana over a period of years ranging from 4 to 7. One of the 3 experimental areas was discontinued due to lack of grassy weed control and at 1 of the other 2 locations were plots chemically treated to control weeds were highly infested with cheat grass. Plots treated with chemicals only and not tilled resulted in soil compaction problems and in such plots they encountered difficulty in seeding operations and stands were reduced.

McCalla (46), and McCalla and Army (47) indicated that the occurrence of diseases and insects appeared to be of no great concern. They also reported that populations of bacteria, actinomycetes, and

nematodes were higher in the surface inch of stubble-mulch-tilled soil. On the other hand, Ledingham et al. (39), in 1960, reported on experiments made between 1951 and 1958, comparing 4 types of seedbed preparation and spore populations of H. sativum and, thus, incidence of root-rot. They found no significant differences between the 4 tillage systems in the incidence of root-rot, except that the incidence of root-rot during the seedling stage was less in plots tilled with the moldboard plow.

Healthy and plump seed are important to the establishment of strong seedling plants. The incidence of poor germination from H. sativum infected wheat kernels has been observed by Christensen (20), Hanson and Christensen (28), Henry (32), Machacek and Greaney (42), and Stakman (66), all of whom also reported that seeds which were infected and germinated resulted in blighted seedlings. Simmonds (61) stated, "the value of sound healthy seed is, in general, readily recognized but must be doubly stressed for areas where root-rots are prevalent."

Mead (49), in 1939, extensively studied 4 commercial grades of Marquis wheat, Nos. 4, 5, and 6 Special and Feed (rusted) and included a check, No. 1 Northern grown in a stem rust free area. These seed lots were treated with formalin, exposed to freezing, drought and disease, and then tested for emergence, and root and shoot development. The seeds and seedlings from shrivelled seeds produced more weak seedlings, were injured more severely by formalin treatment, and were highly susceptible to pre-emergence blight by H. sativum.

Taylor and McCall (68), in 1936, made an extensive study on the morphology of wheat and found that there are 2 important seedling characters that determine the strength of early growth of the wheat

plant. These were the length of the coleoptile and the length of the sub-crown internode. Allan et al. (1), in 1961, reported that coleoptile and culm length were highly heritable characters, and this has since been confirmed by Sunderman (67). Dosdall (24), in 1923, observed germ tubes of H. sativum penetrating both coleoptiles and basal leaves of wheat, and Tisdale, et al. (70) confirmed that the coleoptile was a most delicate organ through which disease organisms made their way into the plant. Indeed, Ledingham (35), in 1961, and later Verma et al. (71) used the hypocotyl or sub-crown internode for the isolation of H. sativum and for disease rating. Sallans (54), in 1961, reported varietal differences and depth of crown in relation to common root-rot caused by H. sativum and Fusarium sp., and Last (33), in 1971, recognized the importance of examining the early infections of the hypocotyl and stated, "the reasons for our inadequate knowledge of the many activities of the soil-borne pathogen can largely be found in the root pathologists predilection for a single end-of-season observation."

Since the root- and foot-rot fungi attack the seedling at an early age, and may even be borne on the seed that is planted, it would be expected that chemical seed treatment would be recommended for control.

Simmonds and Scott (62) noted that much attention had been given to treating seeds against fungi which attack the young seedlings causing non-emergence and seedling blight, and also recognized that treatment itself caused failure of seed germination or seedling emergence. They concluded. "a seed treatment to approach perfection should not injure germination and should protect the seedling from infection of soil fungi during its early stages of development. It should likewise kill

or retard fungi which may be on or in the seed."

Most seed treatment tests were directed toward the control of bunt and loose smut, but there were studies of root-rot control also (62, 17, 15, 64). Among the first chemicals to be used was formaldahyde (41, 70) which was then largely replaced by the mercury-containing compounds (41, 23, 17). More recently, since the mercury-containing compounds have been withdrawn from the market by the Environmental Protection Agency of the U. S. Government, newer, less toxic chemicals are being tested (17, 14, 2, 23), as well as other means of control. Smiley et al. (64), in 1970, reported that liquid anhydrous ammonia injected into the soil was effective against F. culmorum, and while they doubted the practicality of such a treatment, preplant anhydrous ammonia is widely used now in Oklahoma as a source of nitrogen fertilizer.

As early as 1949, Ledingham et al. (38) reported that wheat seeds treated with formalin became devoid of their surface bacterial populations. Seeds so treated became readily attacked when inoculated by H. sativum, compared to untreated seeds. They suggested that natural seed-surface bacteria normally interfere with the development of the root rotting fungus H. sativum. They have also showed that the number of bacteria on the surface of wheat seeds increased when moistened with water. Seeds so treated were more resistant to the pathogen and seedlings were healthier. Similar results were obtained when bacterial suspensions were applied to seeds prior to inoculation with H. sativum.

Although differences in disease reaction among wheat varieties were noted early by McKinney (48), Stakman (66), and Christensen (20), this method of control has not been effective (11). Sallans (55) in

1965, revived the idea that efficient control of common root-rot appears to lie in the creation of resistant varieties. However, the researcher suggested that this may be difficult to accomplish since there is an apparent absence of sources of immunity or high resistance and a lack of suitable techniques for screening varieties and selections. In the normal selection process, lines most susceptible to root-rot have undoubtedly been eliminated in most wheat breeding programs, but this process has not been successful in raising the level of root-rot resistance high enough to control losses when disease incidence is high. Sallans (55) noted that Thatcher, one of the more resistant spring wheat cultivars, may occasionally be 100% infected by C. sativus under conditions conducive to the development of the root-rot disease. More recently, Harding (29) screened 5,500 wheat lines obtained from different geographic and climatic regions of the world and found 112 lines were promising. Further testing revealed 4 lines significantly more resistant to root-rot in the field than anything currently being grown. He believed that since existing lines from different geographic sources have resistance to common root-rot diseases, these resources should be utilized before attempt is made to introduce resistance from exotic Triticum species.

CHAPTER III

MATERIALS AND METHODS

Seed Treatment Tests

Seed treatment tests were made at 2 locations in each of 2 years, 1972-73 and 1973-74. In 1972-73 one test was made on the Plant Pathology Farm, Oklahoma State University, Stillwater, Oklahoma and the other on the North Central Agronomy Research Station, Lahoma, Oklahoma. In 1973-74 the test on the North Central Agronomy Research Station was continued and 1 test was made on the Caddo Peanut Research Station, Ft. Cobb, Oklahoma. The chemicals used in 1972-73 are given in Table I and those used in 1973-74 are given in Table II. These chemicals included liquids, slurries and dry powder. The liquid and slurry chemicals were applied to 4.5 kilogram lots of seed using a Mistomatic Model LA seed treater after which the treated seeds were air dried. The dry powder fungicides were also applied to 4.5 kilogram lots of seeds, but with a motor-driven, bucket-type, mechanical seed treater. All treated seeds were placed in Kraft paper bags and stored until planting. In both the 1972-73 and 1973-74 tests, 2.5 kilogram lots of wheat and barley seed already treated with the 'L205' and 'LT2' fungicides were received from Olin Chemical Company. In all 4 tests the hard red winter wheat, 'Danne' and winter barley, 'Will' cultivars were used. Seed was purchased on the open market in Oklahoma. In

TABLE I

LIST OF CHEMICALS, THEIR ACTIVE INGREDIENTS, RATES AND SUPPLIERS FOR SEED TREATMENT STUDIES MADE IN 1972-73

Brand Name or Number	Active Ingredients	Rate gm/ Kg Seed	Supplier
APO 327	Confidential	2.1	Merck
APO 328	Confidential	2.1	Merck
APO 3210	Confidential	2.1	Merck
APO 3211	Confidential	2.1	Merck
APO 32664	Confidential	2.1	Merck
MERTECT ST SEED TREATMENT	60% Thiabendazole	4.2	Merck
MERTECT 20-S-20	40% Thiabendazole	4.2	Merck
ME-110	Confidential	6.3	Merck
ME-77	Confidential	4.2	Merck
ACTI-DIONE THIRAM	0.75% Cyclohexamide & 75% Thiram	4.2	Tuco
CAPTAN-MANEB-HEXACHLORO-BENZENE (HCB) 20-20-20	20% Captan, 20% Maneb & 20% Hexachloro-benzene (HCB)	2.1	Corn State Hybrid Service
CAPTAN-MANEB-TERRACLOR-TERRAZOLE	27,27,14.4 & 3.6	2.1	Corn State Hybrid Service
CAPTAN-TERRACLOR	42 & 42%	1.6	Corn State Hybrid Service
DITHANE M-45	80% Maneb & Zinc ion	3.0&6.3	Rohm & Haas
DIFOLATAN 4 FLOW	39% Captafol	1.0	Ortho
ORTHO WHEAT SEED PROTECTANT	20% Captan & 20% HCBN	1.0	Ortho
ORTHOCIDE-HCB 2-2 CC-3432	37% Hexachloro-benzene (HCB)	2.1	Ortho
KOCIDE 404	30% Cupric Hydroxide	6.3&12.6	Kennecott
L205[a]	23.2% PCNB & 5.8% Terrazole	2.1&6.3	Olin
LT2[a]	24% PCNB	2.1&6.3	Olin
SEED-TREAT #20	Confidential	1.6	Haynes & Morgan
SEED-TREAT #40	Confidential	1.0	Haynes & Morgan

[a] Fungicides used to treat both wheat and barley seeds.

TABLE II

LIST OF CHEMICALS, THEIR ACTIVE INGREDIENTS, RATES AND SUPPLIERS FOR SEED TREATMENT STUDIES MADE IN 1973-74

Brand Name or Number	Active Ingredients	Rate gm/ Kg Seed	Supplier
DIATHANE M-45	80% Maneb and Zinc Ion	2.1	Rohm & Haas
GRANOX N-M (Powder)	50% Maneb & 10% Hexachloro-benzene (HCB)	1.0	I.C.I.
GRANOX N-M (Flowable)	25% Maneb & 5% Hexachloro-benzene (HCB)	1.7	I.C.I.
L205[a]	23.2% PCNB & 5.8% Terrazole	2.1	Olin
L205 + ZINC OMADINE[a]	23.2% PCNB, 5.8% Terrazole + Zinc Omadine	2.1	Olin
LT2[a]	24% PCNB	2.1	Olin
LT2 + ZINC OMADINE[a]	24% PCNB + Zinc Omadine	2.1&0.3	Olin
MRC-156	Confidential	1.9&3.1	Mineral Research & Development
MRC-156C	Confidential	1.9&3.1	Mineral Research & Development
MRC-156V	Confidential	1.9&3.1	Mineral Research & Development
MRC-156VC	Confidential	1.9&3.1	Mineral Research & Development
M3854	Confidential	0.2&0.3	Dow
SN153	Confidential	1.0,1.4&1.7	NOR-AM
SN43410	Confidential	1.0&2.0	NOR-AM
TOPSIN-M	70% Thiophanate-methyl	2.5&5.0	Pennwalt
VITAVAX 200[a]	17% Carboxin & 17% Thiram	2.0	Uniroyal

[a]—Fungicides used to treat both wheat and barley seeds.

all cases the seed lots were cleaned prior to treatment.

In 1972-73 each seed treatment plot consisted of 6 rows 30 cm apart and 20 m long and planted on September 26, 1972 at Stillwater and on September 28, at Lahoma. There were 31 treatment entries on wheat including 2 untreated checks and 5 treatment entries including one check on barley at both locations.

In 1973-74 a completely randomized block design of 29 treatments (including 4 untreated checks) and 7 treatments (including 2 untreated checks) on barley in 4 replications was used in each location. Each plot consisted of 4 rows 25 cm apart and 3 m long.

In 1972-73 the soil condition after planting remained extremely wet and no notes could be taken until December 28, when tiller counts were made in each plot at Stillwater. Counts of the number of tillers were made in 3 separate one meter sections of row chosen at random in 1 of the 4 center rows of each plot. The plots at Lahoma remained wet and no notes were taken.

In 1973-74 a germination test was conducted on the wheat and barley seed lots treated with the different chemicals. Five lots of 100 seeds of each barley and wheat treatment picked randomly were placed between folded wet blotter papers placed in a seed germinator. Germination in each lot was counted at the end of 7 days.

On October 25, 1973, emergence counts were made in the plots at the Caddo Station and a stand count was made on November 13, 1973. In each plot a section of row, 1 m long, was measured at random on either of the 2 center rows of the plot. The number of plants emerged in this area was counted and the stand count was made later from the same 1 m of row. The study at Caddo, Ft. Cobb, Oklahoma, was terminated

after stand counts were made.

At Lahoma, emergence and stand counts were made in the same manner on November 18, 1973 and February 2, 1974, respectively. In addition, on April 13, 1974, 30-plant samples were taken from 5 randomly chosen locations within each plot of each of 2 replications. Enough plants to make a 30-plant sample for each entry were collected. Samples were only taken from the first 2 replications of each entry. Each sample was placed in a polyethylene bag, brought to the laboratory and held in a refrigerator at 4C until the roots and foliage could be washed.

After soaking each sample for 30 minutes to 1 hr., the roots and foliage portions were washed gently in running tap water. Each plant in each sample was then visually examined for root disease lesions. Following this examination attempts were made to isolate H. sativum from diseased portions of these plants.

Throughout these investigations the procedure for making isolations remained constant. The portions of hypocotyls, basal leaves, primary and secondary roots, and coleoptiles were surface sterilized and plated on acidified (with lacti acid to pH 4.7) potato-dextrose medium. The procedure of surface sterilization followed was to vigorously shake the samples for 15 seconds in water to remove soil particles then place them on paper towels to remove the excess water. These partially moist samples were then placed in a 1.25% solution of sodium hypochlorite and again shaken vigorously for 45 seconds, and in 3 changes of sterilized distilled water. After the third rinsing, the sample was placed between folds of sterilized paper towel and then aseptically plated on acidified potato-dextrose medium in petri dishes. Five pieces

were placed in each petri dish. Plated dishes were placed in new polyethylene bags and stored at room temperature for 120 hrs. At the end of that time colonies of H. sativum and Fusarium sp. were recorded.

After small portions of plant parts suitable for isolation were saved, the root portions of each sample were removed at the crown, placed in Kraft paper bags and dried at 57C for 96 hrs. Each sample was then weighed.

On May 29, 1974, the number of sterile heads presumably caused by H. sativum and other root-rotting fungi and the number of heads smutted by Ustilago tritici or U. nuda as the case may be were counted in each plot. Then on June 11, 1974, one 4.9 m/row from each plot was harvested and the grain yield and test weight were measured.

Controlled Environment Tests

An experiment was designed to investigate interactions of 2 root-rot pathogens at 2 temperatures and with 2 wheat cultivars.

The 2 organisms, H. sativum and Fusarium sp. were obtained from single spore insolations from infected wheat plants brought from the field plots at the North Central Agronomy Research Station, Lahoma, Oklahoma. The pathogenicity of the 2 isolates was determined in a preliminary test. Clean, surface sterilized (1% soldium hypochlorite for 5 minute) seed of the cultivar 'Danne', a commonly grown hard red winter wheat and 'Aniversario', a cultivar developed and grown in Argentina which has shown a high incidence of dry-land-foot-rot in disease monitoring plots in Oklahoma were chosen for the study.

The inocula, H. sativum and Fusarium sp. were grown on a medium consisting of a mixture 7 parts wheat and 5 parts oats. Two hundred

and fifty ml of this medium was placed in each of twelve 500-ml Erlenmeyer flasks to which 100 ml of distilled water was added. The flasks were then plugged with cotton and steam sterilized twice with an interval of 48 hrs. between sterilizations. Five of the flasks were asceptically inoculated with H. sativum and 5 with Fusarium sp. from stock cultures growing on potato-dextrose agar in petri dishes. These fungi were allowed to grow for 2 weeks at which time the medium was permeated thoroughly by mycleium. Two flasks of the medium were not inoculated and the sterile medium was used for a control.

A Pond Creek-Silt Loam soil obtained from a field adjacent to the tillage-foot rot study plot at the North Central Agronomy Research Station, Lahoma, Oklahoma, was brought to the laboratory, pulverized, run through a 40-mm screen, mixed one-to-one with sharp builder's sand and steam sterilized twice for 18 hrs. with an interval of 48 hrs. The 15 cm clay pots used in the experiment were steam sterilized once for 12 hrs. These sterlized pots and soil were stored in sealed containers until used. Two Sherer Gillette Model Cel 37-14 control environment chambers, 1 adjusted for a constant temperature of 18C and the other for a constant temperature of 30C were used. The plant bed in each chamber was adjusted to provide a light intensity of 13455 lux at the top of the pots and both chambers were adjusted to provide a 14-hour photoperiod.

Sixty four sterilized 15 cm diameter pots were filled with 880 ml of the soil-sand mixture and 25 seeds of the cultivar 'Danne' were evenly distributed over the surface of the soil in each pot. The seeds were covered with 40 ml of the soil-sand mixture. Then, 16 of the 64 pots were infested by spreading 4 grams of inoculum of H. sativum

evenly over the surface of the soil, 16 pots were infested with 4 grams of inoculum of Fusarium sp. and 16 pots with a combination of 4 grams of H. sativum and 4 grams of Fusarium sp. inoculum mixed together, and the soil in the final 16 pots was covered with the sterile wheat-oat medium to serve as a control.

Finally, each of these 64 pots was carefully topped with 40 ml of the sterilized soil-sand mixture to cover the inocula. One half (8) of the pots of each treatment were placed randomly in the growth chamber adjusted to 18C and the other half in the growth chamber adjusted to 29C.

The water used for a regular daily application was preheated for at least 24 hrs. in the same chamber where it was to be used and contained sufficient 'Hyponex' fertilizer to make a solution containing 2% nitrogen.

Throughout the course of the 60-day experiments the position of the pots within a growth chamber was changed randomly every 5 days to reduce variation due to location with the chamber. The experiment was conducted for a full 60 days but some of the pots were removed for disease observation in 3 intervals of 25, 40, and 60 days after the date of planting

Twenty five days after planting, 2 pots of each treatment and the check from each chamber were removed and examined. To accomplish this, the pots of plants were soaked in water for 30 minutes after which the soil was washed gently from the roots over a 0.25 cm screen. After the roots were washed, the excess water was sponged-off with paper towels, the plants were sealed in clean polyethylene bags and kept in the refrigerator at 4C until examinations for disease could be made.

The total number of plants and the number of plants with root-rot disease symptoms was recorded. Each plant was severed with scissors at the crown and the root and foliage portions placed separately in Kraft paper bags and dried for 96 hrs. at 57C. The dry weight of both root and foliage was measured.

Ten 2-cm-long portions of hypocotyls, primary roots, secondary roots and the bases of primary leaves from the plants in each pot were used for reisolation of the test organisms. Isolations were made on acidified potato-dextrose agar. The techniques for the preparation of these isolations has been described previously.

Forty days after planting, 2 more pots were removed from each of the treatments in each of the 2 chambers and examined in the same manner, except that in this group the length of the foliage growth was also measured.

This experiment was terminated 60 days after planting and the remaining pots, 4 in each treatment and the check from each chamber, were removed and examined.

The entire experiment was duplicated using the cultivar 'Aniversario' instead of 'Danne'.

Tillage Level Studies

A study to investigate the incidence of root-rot in 4 tillage systems was conducted in 2 crop seasons (1974 and 1975) at one location and 1 crop season at a relocated site in 1976.

The experiments in all 3 years were made at the North Central Agronomy Research Station, Lahoma, Oklahoma. The experimental plot was divided into 4 replications each with 4 tillage levels. Each

tillage level plot, measured 10 by 24 m and was divided into 2 sub-plots 5 by 24 m for early and late planting dates. The planting date sub-plots were further divided into plots measuring 10 rows 25 cm apart by 24 m long. One of these sub-plots was planted with treated seed and the other with untreated seed.

The 4 tillage levels described above were: (1) plowed - the seedbed was clean plowed after harvest using a moldboard plow, followed by spring tooth harrow cultivation for weed control during the summer and for seedbed preparation; (2) sweep - the seedbed was 'stubble mulched' with a 'sweep' type implement after harvest which disturbed only the top two inches or so of the soil, followed by continued use of the sweep when weed control was required, (3) sweep and chemical - in addition to cultivation with the sweep implement after harvest a chemical herbicide 'Paraquat', (1,1'dimethyl-4,4'-bipyrdinium ion) at a rate of 4.7 l of formulation per ha was used to control weeds when necessary; and (4) sweep and disc - sweep cultivation after harvest and whenever weed control was required and disc-harrowed prior to planting.

The cultivar selected for the experiment was the hard red winter wheat, 'Danne'. Untreated seed of this cultivar were obtained each year from the commercial market in Oklahoma.

The seed was cleaned with a mechanical seed cleaner and 18 kg of the cleaned seed were treated with 36 ml of Vitavax 200 (carboxin-5,6-dihydro-2-methyl-1, 4-oxathiin-3-carboxanilide-17%, and thiram tetramethylthiuram disulfide-17%) flowable formulation for use in the treated sub-plots, and an equal amount of untreated seed was used in the control plots. The fungicide was applied to the seed by diluting 36 ml of the slurry with 100 ml of distilled water and spraying this

solution on the seed while being rotated in a motor-driven bucket type treater. A germination test was conducted on 5 lots of 100 seed of chemically treated and 5 lots of untreated seed.

In the fall of 1973 the early-planted plots were sown on September 22 and the late-planted plots on October 10. The plots were planted with 10-row John Deere 'Hoe Drill'. In 1974, the early planting was made on September 30, and the late planting on November 15. In 1975, there was insufficient moisture for planting until Ocotber 30, at which time both the 'early' and 'late' plots were planted.

Throughout these tests, emergence, stand, number of tillers, percent of measurable hypcotyls, length of hypocotyl, root-and foliage-dry weight, grain yield and test weight were measured. Emergence in each sub-plot for the 1974 crop year was taken on October 18, 1973, in the early planting date plots. Emergence was counted in 1 m of row selected randomly in each plot. These selected sections were marked, and later used for final stand counts that were made on November 30, 1973. On March 15, 1974, the plants in these sections were dug to obtain root- and foliage-dry weight. Portions of plant parts of these samples also were used for disease examination. The samples were sealed in polyethylene bags and kept in a refrigerator at 4C until examination was made. Each sample was soaked in water for a period of 30 minutes to 1 hr., then the roots of each sample were gently cleaned in running tap water. Also, the leaves were rinsed clean. The excess water on the samples was blotted dry with paper towels. Thirty plants were randomly selected in each sample. The hypocotyls of these 30-plant samples were measured to determine the percent of plants with measureable hypocotyls and the average length of those that were long enough to measure. In

addition each plant was examined for lesions on the hypocotyl, the roots and the basal portion of the primary leaves. Ten 2-cm portions of hypocotyls with lesions, ten 2-cm portions of primary leaves with lesions and ten 2-cm portions of primary and/or secondary roots with lesions were selected for isolation. These plant portions were surface sterilized and plated on acidified potato-dextrose agar in petri dishes. Each of the plants was then severed with a pair of scissors at the crown and the root and foliage was dried separately for 96 hrs. at 57C and weighed.

On May 18, 1974, similar samples were obtained from plants having white, sterile heads indicative of root-or foot-rot. Small portions of crown tissue were excised from these plants for isolation, but basal tissue of the primary leaves was no longer present and could not be used.

On June 11, 1974 two 4.9 m/row samples were selected at random, harvested and thrashed to obtain grain yield and test weight.

Similar data on late planting date plots were obtained differing only in the dates the observations were made. Emergence and stand counts were made on November 18, 1973, and February 2, 1974, respectively. Plants were collected for isolation and for root-and foliage-dry weight on March 15, 1974. Grain yield harvest was made on June 11, 1974.

In 1974 emergence was counted on the early planted plots and on December 12 on the late planted plots. Stand counts and plant collections on the early planted plots were made on November 15, 1974.

A second stand and tiller count together with measurements of hypocotyl length and root-and foliage-dry weights was made on March 22, 1975. Adverse weather delayed stand counts and plant collections

on the late planted plots until April 6, 1975.

On May 16, 1975 growth uniformity, lodging, loose-smutted heads and the presence of weeds were noted on all plots. a rating scale of 0 to 9 was used for all characteristics (except smut) where the lower numbers indicated more desirable characteristics and the higher numbers less desirable (40).

On June 5, 1975, the number of sterile heads (presumably caused by root-or foot-rot) were counted in each plot and 10 plants with such heads were dug from each tillage level in replications one and two. Isolations were made from the hypocotyls, pea-size pieces excised from the crown of the plants, and also from 2-cm sections of the secondary root system. Both early and late planted plots were harvested on June 29, 1975.

The location of the study during the crop seasons 1973-1975 was in a site where several of the plots were on a slope and erosion was a problem. Furthermore, the tillage plots with sweep cultivation after harvest followed by chemical weed control were difficult to manage due to hard-packed soil conditions at planting time and weed problems after planting.

Therefore, in the fall of 1975 the entire experiment was relocated and the sweep-chemical tillage system was discontinued. All other factors including the plot size remained the same as in previous years.

On November 28, 1975, emergence was counted and at the same time plants removed for stand and tiller counts, for measurement of the hypocotyls and for isolation purposes. Since the coleoptiles were still intact at this time, isolations were made from coleoptile tissue as well.

In addition, notes were taken on January 30, 1976, for the amount of infestation of cheatgrass (Bromus secalinus L.(25) and on February 25, 1976, the degree of wind damage was recorded.

During the spring of 1976 H. sativum infections appeared on the leaves in the plots and on May 11, 1976, the percent of blighted leaves from both the flag leaves and the first leaf below the flag leaf was estimated.

On June 3, 1976, the appearance of the plots was rated for density of stand and for the amount of sterile heads, presumably caused by root-rot or foot-rot. The plots were not harvested for grain yield measurements.

CHAPTER IV

RESULTS

Seed Treatment Tests

Experiments to test the effectiveness of various seed treatments on wheat and barley were made in the 1972-1973 crop season at 2 locations, Stillwater and Lahoma, Oklahoma. Excessive rainfall after planting prevented emergence counts or seedling plant samples, but a stand count was made at Lahoma and yields were measured at both locations. These data are presented in Table III. No treatment produced a better stand than the untreated controls at Lahoma; in fact, many treatments had significantly fewer plants than the controls. Likewise, no treatment yielded better than the control at either location, and several treatments had significantly less yield. The data suggest that seedling blight, root-, or foot-rots were not significant factors in these experiments, and that some phytotoxic effects may have been experienced.

There were no statistical differences among the 4 barley seed treatments in those experiments.

In the 1973-74 season a total of 25 seed treatments were applied to wheat and 5 to barley, and planted at 2 locations, Lahoma and Caddo, Oklahoma (Table IV). Germination tests of treated seeds conducted in the laboratory showed no difference among treatments, but

TABLE III

YIELD AND FINAL STAND COMPARISON OF DANNE WHEAT TREATED WITH SEED TREATMENT FUNGICIDES IN 1972-1973 CROP SEASON

	Chemicals	Rates gm/kg seed	Final Stand Plants/m	Grain Yield q/Ha[a]
1.	L205	2.1		
2.	L205	6.3		
3.	LT2	2.1	<<	
4.	LT2	6.3		
5.	THIOGEN TCMTB	0.8	<<	
6.	SEED TREATMENT #20	1.6	<<	
7.	SEED TREATMENT #40	1.0		
8.	DITHANE M-45	3.1	<	
9.	DITHANE M-45	6.3		
10.	GRANOX N-M	1.0	<<	
11.	MERTECT ST (60% THIABENDAZOLE)	4.2	<<	
12.	MERTECT 20-S-20 (40% THIABENDAZOLE)	4.2	<<	
13.	ME-77	4.2	<<	
14.	ME-110	6.3	<<	
15.	CAPTAN-MANEB HCB 20-20-20	2.1	<<	
16.	CAPTAN-MANEB HCB	2.1		
17.	CAPTAN-MANEB-TERRACLOR-TERRAZOLE	2.1	<<	
18.	CAPTAN-TERRACLOR (42-42)	1.6		
19.	DIFOLATAN 4 FLOW	1.0	<	
20.	ORTHOCIDE-HCB 2-2 CC 3432	2.1	<<	<
21.	ORTHO (WHEAT SEED PROTECTANT)	1.0	<	<
22.	ACTI-DIONE-THIRAM	4.2	<	<
23.	APO 32664	2.1		<
24.	APO 3211	2.1		<
25.	APO 3210	2.1	<	
26.	APO 328	2.1	<	<
27.	APO 327	2.1	<<	<<
28.	KOCIDE 404	6.3		
29.	KOCIDE 404	12.6	<	
30.	CHECK (MEAN OF TWO PLOTS		44.5	24.0
	LSD .01		12.4	3.9
	LSD .05		9.3	2.7

<< = Denotes treatment means that are less than the mean of the 2 check plots at the .01 level of probability

< = Denotes treatment means that are less than the mean of the 2 check plots at the .05 level of probability

/a q (Quintal), 100 Kg weight.

TABLE IV

EMERGENCE, FINAL STAND, NUMBER OF DISEASED PLANTS, ROOT DRY WEIGHT, STERILE HEADS, AND YIELD OF THE CULTIVAR DANNE TREATED WITH VARIOUS SEED TREATMENT FUNGICIDES IN 1973-1974 CROP SEASON

Chemicals	Rates gm/Kg Seed	Emergence[a]	Final Stand[a]	% Infected Plants by Root Rot Pathogens[a]	Root Weight in Grams[b]	Number of Sterile Heads[b]	Grain Yield q/ha[b]
L. M3854	0.3	*				<	
2. M3854	0.2			<			
3. L205 + Zn OMADINE	2.1+0.2						
4. L205	2.1			<			
5. LT2 + Zn OMADINE	2.1+0.2	<	<	<			*
6. LT2	2.1						
7. SN513	1.0						
8. SN513	1.4						
9. SN513	1.7			<			
10. SN43410	1.0					<	
11. SN43410	2.1						
12. GRANOX N-M (POWDER)	1.0	<	<				
13. GRANOX N-M (FLOWABLE)	1.7	<	<				
14. DITHANE M-45	2.1	<	<	<			
15. VITAVAX-200	2.0				*		
16. MRC-156	1.9	<	<	<			
17. MRC-156	3.2	<	<	<	*		
18. MRC-156C	1.9	<	<				

TABLE IV (CONTINUED)

Chemicals	Rates gm/Kg Seed	Emergence[a]	Final Stand[a]	% Infected Plants by Root Rot Pathogens[a]	Root Weight in Grams[b]	Number of Sterile Heads[b]	Grain Yield q/Ha[b]
19. MRC-156C	3.2	<	<	<			
20. MRC-156V	1.9			<			
21. MRC-156V	3.2		<				
22. MRC-156VC	1.9	<	<	*	*	<	
23. MRC-156VC	3.2	<	<				
24. TOPSIN-M	2.5	<	<				
25. TOPSIN-M	5.0	<	<	<			
26. CHECK (MEANS OF FOUR PLOTS)		39.1	39.3	21.6	2.9	1.4	17.9
LSD .05		3.6	3.0	4.4	0.6	1.3	1.8

[a] = Combined results from 2 locations, Lahoma and Caddo Research Stations.

[b] = Results obtained from Lahoma Research Station only.

* = Denotes the means that are higher than the mean of 4 check plots at the .05 level.

< = Denotes the means that are less than the mean of 4 check plots at the .05 level.

chemically-treated seeds germinated better than the untreated seeds.

Emergence and final stand counts of both wheat and barley in these experiments were essentially the same at both locations. The chemical, M3854, at a rate of 0.3 gm/Kg, resulted in significantly better emergence at both locations. However, many treatments resulted in significantly lower emergence than the untreated controls.

The experiment at Caddo, Ft. Cobb, Oklahoma was terminated after the final stand counts were made, but the experiment at Lahoma was continued through harvest. Examination of root portions of wheat plants 167 days after planting revealed that those from many of the treated plots were free of root-rot diseases. Among these treatments was the chemical, M3854, which had produced better emergence and which also produced significantly less sterile heads at the pre-ripening stage. Also the treatments, SN43410 at a rate of 1gm/Kg and MRC-156VC at a rate of 1.9 gm/Kg had significantly less sterile heads. MRC-156VC, however, at rates of 1.9 gm and 3.2 gm/Kg produced significantly less emergence and stand but higher root weight. Vitavax 200 seed treatment also had a lower plant stand but produced a higher mean root weight per plot sample. Also, the treatment LT2 plus Zinc Omadine at a rate 2.1 gm and 0.2 gm/Kg, respectively, yielded more and had less evidence of root-rot than the untreated controls in spite of a lower emergence and plant stand.

When the plants were examined for root-rot, the pathogens responsible for the lesions were isolated. Neither H. sativum or Fusarium sp. were isolated in significant numbers from diseased roots in these experiments.

The barley treatment results are presented in Table V. It was

TABLE V

LOOSE SMUT CONTROL AND GRAIN YIELD OF THE BARLEY CULTIVAR 'WILL' TREATED WITH CERTAIN SEED TREATMENT FUNGICIDES IN 1973-74 CROP SEASON

Name of Chemicals	Rate gm/Kg Seed	Percent Loose Smut	Grain Yield q/Ha
1. LT2	2.1	6.6	18.5
2. LTS plus ZINC OMADINE	2.1 + 0.2	15.0	19.2
3. L205	2.1	0	18.9
4. L205 plus ZINC OMADINE	2.1 + 0.2	0	18.9
5. VITAVAX 200	2.0	6.3	20.6
6. CHECK (MEANS OF TWO CHECK PLOTS)		47.7	17.5
Loose smut LSD .01		18.7	
Yield LSD .05			1.9

found that all 5 treatments gave at least partial control of loose smut, and 2, L205 at a rate of 2.1 gm/Kg, and L205 plus Zinc Omadine at rates of 2.1 gm and 0.2 gm/Kg fully controlled this disease. Treatment with Vitavax 200 resulted in a higher grain yield than the untreated checks.

Controlled Environment Tests

Emergence and final stand counts of either cultivar, Danne or Aniversario, did not differ when pots were infested with the pathogens, H. sativum and Fusarium sp. at 3 different levels either singly or in combination and held for 60 days at either 18 or 30C temperature in growth chambers. However, when plants were examined after washing the soil from the roots at 25, 40 and 60 days after planting both H. sativum alone and in combination with Fusarium sp. produced progressively more severe symptoms on hypocotyls, crown areas, and the lower portions of foliar parts of the plants with increasing age of the plants. Pictures of washed plants of the cultivar Danne after 60 days of growth at 18C and 30C are presented in Figures 1 and 2, respectively. Although all plants had weak culms in these experiments the effect of infestation with H. sativum alone and together with Fusarium sp. was evident in the amount of growth at both 18C and 30C (Figures 3 and 4).

Although the culture of Fusarium sp. used in this study proved pathogenic to wheat seedlings in preliminary tests, it did not produce any pronounced symptoms on either the above ground (Figure 3 and 4), or below ground (Figure 1 and 2), plant parts.

The percent of plants infected with H. sativum was recorded 40 and 60 days after planting. The data presented in Tables VI and VII,

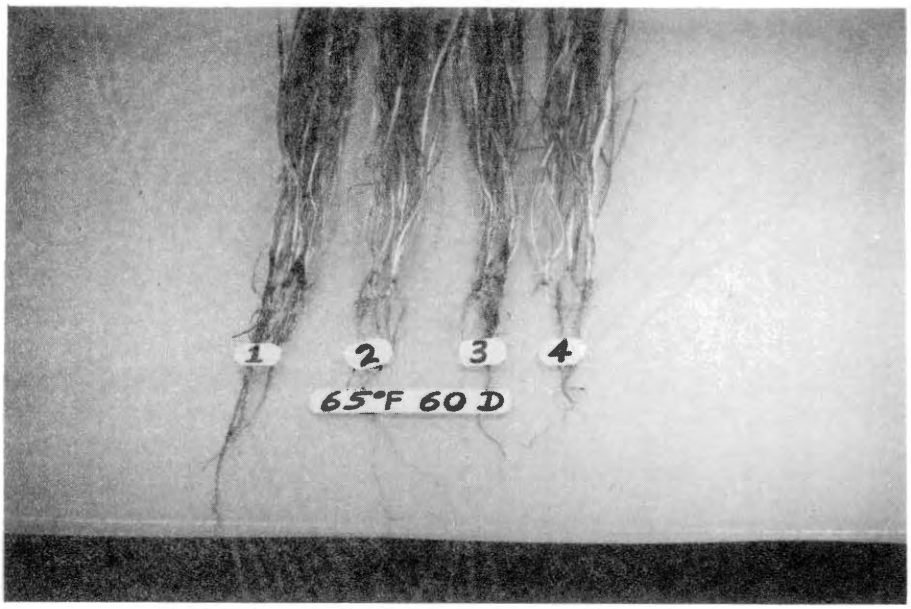

Figure 1. Sixty-day old seedlings of the wheat cultivar Danne grown in a growth chamber at 18C and infested with (1) Helminthosporium sativum alone, (2) Fusarium sp. alone, (3) Helminthosporium sativum and Fusarium sp. combined, and (4) noninfested control.

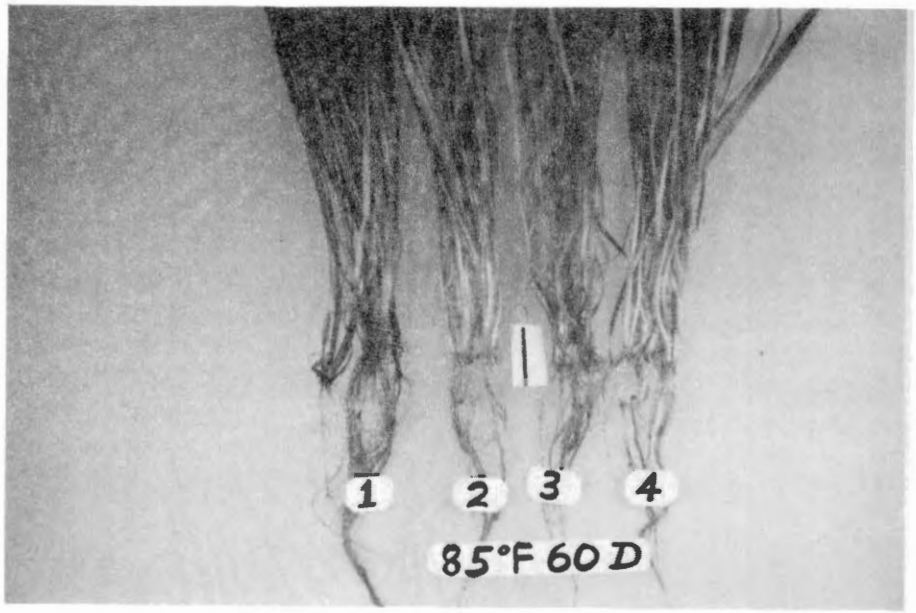

Figure 2. Sixty-day old seedlings of the wheat cultivar Danne grown in a growth chamber at 30C and infested with (1) Helminthosporium sativum alone, (2) Fusarium sp. alone, (3) Helminthosporium sativum and Fusarium sp., combined, and (4) noninfested control.

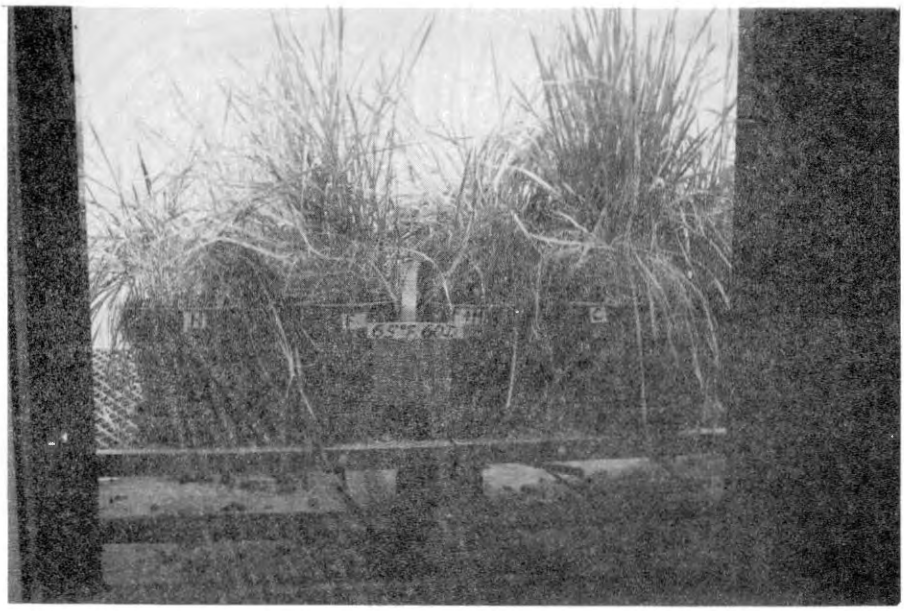

Figure 3. Sixty-day old wheat seedlings of the cultivar Danne grown at 18C in a growth chamber and infested with; (H) Helminthosporium sativum alone,(F) Fusarium sp. alone, (F + H) Fusarium sp. and Helminthosporium sativum combined, and (C) noninfested control.

Figure 4. Sixty-day old wheat seedlings of the cultivar Danne grown at 30C in a growth chamber and infested with; (H) Helminthosporium sativum alone, Fusarium sp. alone, (F + H) Fusarium sp. and Helminthosporium sativum combined, and (C) noninfested control.

TABLE VI

PERCENT OF PLANTS INFECTED BY HELMINTHOSPORIUM SATIVUM AND MEAN NUMBER OF ISOLATES OF HELMINTHOSPORIUM SATIVUM AND FUSARIUM SP. PER POT FROM HYPOCOTYLS, FIRST LEAVES AND PRIMARY AND SECONDARY ROOTS 40 DAYS AFTER SEEDING

		H. sativum Isolates From				*Fusarium sp.* Isolates From			
	% Infected Plants Per Pot/a	Hypocotyls	Bases of First Leaves	Primary Roots	Secondary Roots	Hypocotyls	Bases of First Leaves	Primary Roots	Secondary Roots
CONTROL (NON-INFECTED)	0	0	0	0	0	0	0	0	0
INFECTED WITH *FUSARIUM SP.*	0	-	-	-	-	6.6	4.0	4.8	2.8
INFECTED WITH *F. SP.* AND *H. SATIVUM*	53.5	4.1	6.4	3.6	3.4	5.5	4.9	4.9	3.4
INFECTED WITH *H. SATIVUM*	69.5	4.8	7.3	3.5	5.0	-	-	-	-
LSD .01 =	48.8		4.6	NS	NS	5.6			NS
LSD .05 =		3.5					3.4	2.7	

/a = Percent infected plants rated on the basis of visible symptoms that resulted from infection by *H. sativum*.

TABLE VII

PERCENT OF PLANTS INFECTED BY HELMINTHOSPORIUM SATIVUM AND MEAN NUMBER OF ISOLATES OF HELMINTHOSPORIUM SATIVUM PER POT FROM HYPOCOTYLS, BASES OF FIRST LEAVES, AND PRIMARY AND SECONDARY ROOTS 60 DAYS AFTER PLANTING

Treatment	Mean % Infected Plants per Pot[a]	Hypocotyls	Bases of First Leaves	Primary Roots	Secondary Roots
CONTROL (NON-INFECTED)	0	0	0	0	0
INFECTED WITH *FUSARIUM* SP.	0	-	-	-	-
INFECTED WITH *F.* SP. + *H. SATIVUM*	58.0	5.8	7.9	4.9	2.3
INFECTED WITH *H. SATIVUM*	65.3	7.9	9.5	4.3	4.0
LSD .01 =	59.4	7.3	2.7		
LSD .05 =			1.2	3.4	2.6

[a] = Percent of infected plants based on visible symptoms of infection by *H. sativum*.

confirm that significantly greater infection occurred in pots infested with H. sativum and the combination of H. sativum and Fusarium sp. than the control or pots infested with Fusarium sp. alone.

Hypocotyls, bases of first leaves and primary and secondary roots were used for reisolation of the pathogens on acidified potato-dextrose agar. Reisolation was conducted at the end of 25, 40, and 60 days, but since the data were similar only that for 40 and 60 days are presented.

Plants in pots infested with Fusarium sp. had small water-soaked lesions and the pathogen could be reisolated from these plants (Table VIII), but the effect on the plants appeared to be minimal. When Fusarium sp. were mixed with H. sativum and used to infest pots, the Fusarium appeared to dilute the effect of the Helminthosporium pathogen.

Cultivar Aniversario did not respond to infection by H. sativum as severely as cultivar Danne (Table VIII). At earlier stages 25 and 40 days after planting, visible symptoms of H. sativum infection on Aniversario were difficult to detect. Symptoms first appeared as faint, fine streaks measuring approximately 0.1 mm wide along the veins and mid-ribs of the bases of the lower leaves and on the hypocotyl. Symptoms increased to some degree by 60 days after planting but still were restricted to about 2-3 cm on the above ground parts. More isolates of H. sativum were recorded from infected plants of Danne than from Aniversario.

It was noted that H. sativum tended to be isolated more from hypocotyls, basal portions of leaves and upper primary roots, where as Fusarium sp. tended to be isolated more from lower portions of the hypocotyl and the primary roots.

During the course of these investigations it was noted that when

TABLE VIII

PERCENT OF PLANTS INFECTED BY HELMINTHOSPORIUM SATIVUM AND MEAN NUMBER OF ISOLATES OF HELMINTHOSPORIUM SATIVUM AND FUSARIUM SP. FROM HYPOCOTYLS, BASES OF FIRST LEAVES, AND PRIMARY AND SECONDARY ROOTS OF TWO CULTIVARS, ANIVERSARIO AND DANNE 60 DAYS AFTER PLANTING

CULTIVAR	Mean % Infected Plants Per Pot[a]	Hypocotyls	Bases of First Leaves	Primary Roots	Secondary Roots	Hypocotyls	Bases of First Leaves	Primary Roots	Secondary Roots
ANIVERSARIO	16.4	4.3	5.2	1.5	0.2	0.7	1.9	0.9	0.5
DANNE	45.2	4.8	6.5	4.6	4.0	5.1	4.0	5.8	3.1
LSD .01	21.4								
LSD .05		NS	1.1	1.1	2.6	4.2	NS	1.1	NS

[a] = Percent of infected plants based on visible symptoms of infection by H. sativum.

2 colonies of H. sativum appeared in the same petri plate these colonies would not overgrow one another, but remained distinct (Figure 5). However, colonies of Fusarium sp. would overgrow other colonies of Fusarium sp. and colonies of H. sativum. When 2 single conidiospores of H. sativum were used to initiate separate colonies in a petri dish, these colonies also remained restricted in growth and distinct (Figure 6). However, when a single conidiospore was used to initiate a single colony in a petri dish the growth was not restricted (Figure 7).

Tillage Level Study, 1973-1974

Crop Season

Germination tests showed that seeds treated with Vitavax 200 did not differ in germination from untreated seeds.

Throughout the field studies numerous data were taken at various times during the season. A complete compilation of those data would be extremely complex. Therefore, all data were analyzed statistically and only those comparisons that were significant at least at the 0.05 probability level are given.

At the early planting date, September 22, tillage levels 2 and 3 were rough and trashy and infested with volunteer wheat plants, and tillage level 3 was difficult for the planter hoes to penetrate due to hard-packed soil. During planting most seeds were scattered on or near the surface. In spite of such conditions, and probably because of good soil moisture, plant stand appeared to be as good as in the plots with the best seedbed condition.

At the late planting date, October 10, even tillage levels 1 and 4, with the best initial seedbed preparation, incurred seeding

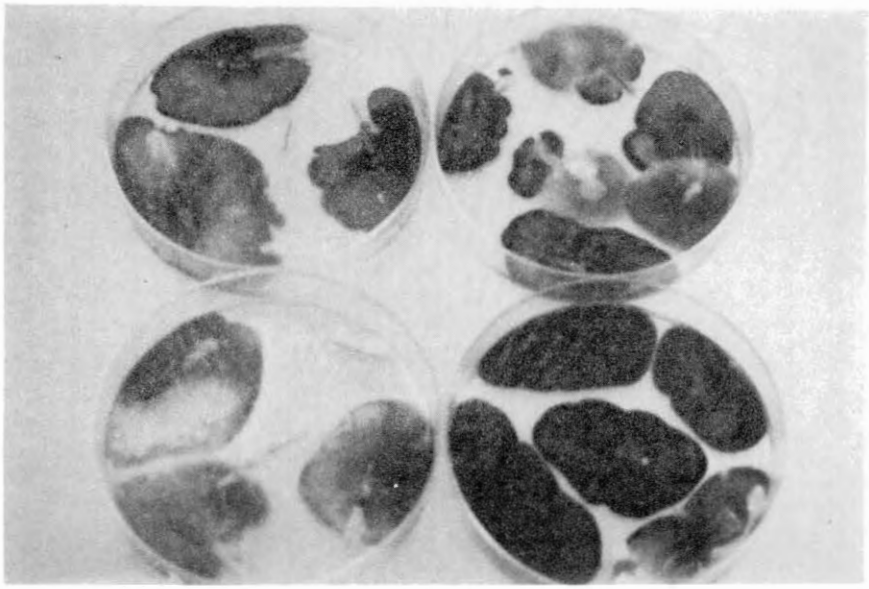

Figure 5. Distinct colonies of 3-week old Helminthosporium sativum isolates grown on acidified potato-dextrose agar.

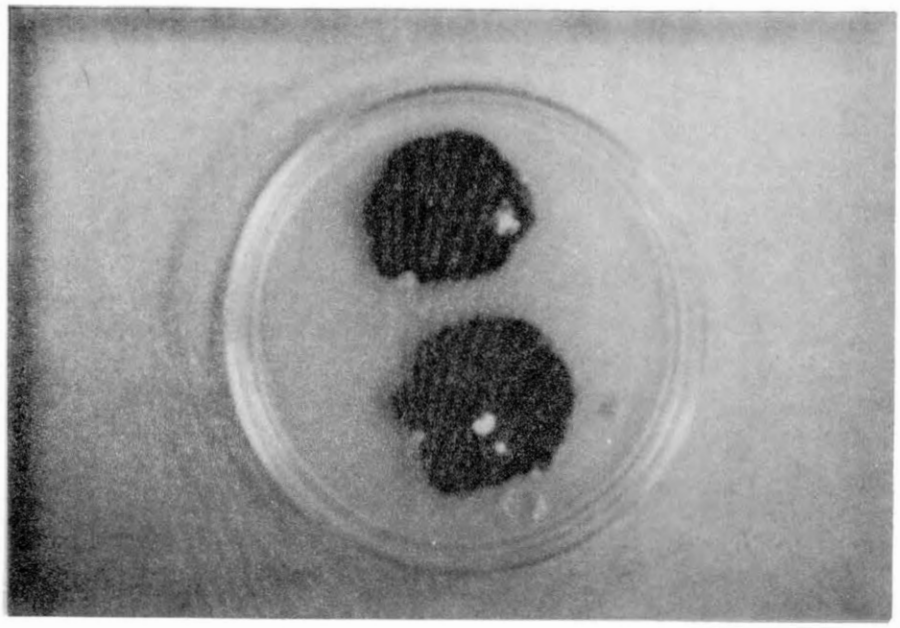

Figure 6. Three-week old colonies of Helminthosporium sativum initiated from single conidiospores and grown on acidified potato-dextrose agar.

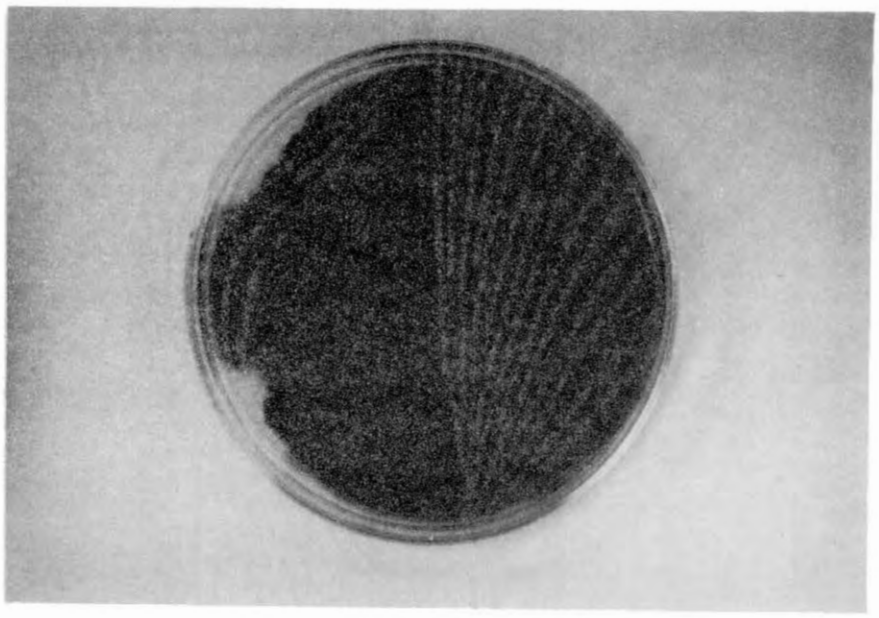

Figure 7. Three-week old colony of Helminthosporium sativum initiated by a single conidiospore and grown on acidified potato-dextrose agar.

problems. During the long period of over a month between seedbed preparation and seeding, the soil became repacked by frequent hard rains to the point that seeds could not be placed to a normal depth.

The moisture condition of the soil during and after planting in the fall of 1973, was relatively good for both early and late planted seed.

Emergence was counted in both early and late planting date plots on October 28, 1973. Because of the wet soil an emergence count in the early plots could not be made until then. There was better emergence from the late planted plots at the time than from the early ones (Table IX), but the difference between the emergence of the 2 planting dates narrowed by the time final stand counts were made on December 2. Foliage-and root-dry weight and yield were higher from the early planted wheat, as would be expected due to differences in the length of the growing period. However, grain yields also were higher for the early planted plots.

Comparisons among tillage levels, Table X, indicated emergence, final stand, yield, foliage-and root-dry weights and grain yield were all significantly greater in levels 1 and 4 than levels 2 and 3.

Hypocotyl development in both early and late planted plots was examined in samples collected on March 15, 1974. Hypocotyl development was nil to very poor even in tillage levels 1 and 4 which had fairly well-prepared seedbeds, particularly at the early planting date. An examination of the few, short hypocotyls that were present revealed very little damage and isolations did not yield any colonies of either H. sativum or Fusarium sp.

In mid- May the white, sterile head syndrome appeared in all plots

TABLE IX

A COMPARISON OF MEANS FOR EMERGENCE, FOLIAGE AND ROOT DRY WEIGHT, AND YIELD IN 'EARLY' AND 'LATE' PLANTED PLOTS IN THE 1973-1974 CROP SEASON

Date of Planting	Emergence: Number of Plants/m row	Foliage Weight in g	Root Weight in g	Grain Yield q/Ha
	10/18/73	3/15/74	3/15/74	6/11/74
EARLY (9/22/73)	22.0	133.0	2.9	20.5
LATE (10/29/73)	26.6	58.9	1.6	9.5
LSD .01 =	3.3	18.0	0.4	1.5

TABLE X

A COMPARISON OF MEANS FOR EMERGENCE, FINAL STAND, FOLIAGE AND ROOT DRY WEIGHT, AND YIELD IN FOUR TILLAGE LEVELS IN 1973-1974 CROP SEASON

Tillage Level	Number of Plants/m of Rows		Foliage Weight in g	Root Weight in g	Grain Yield q/Ha
	Emergence	Final Stand			
1	32.7	39.8	126.7	2.6	15.7
2	19.7	23.1	74.7	1.9	14.7
3	18.9	16.1	77.0	2.1	14.7
4	26.0	34.8	105.4	2.5	15.0
LSD .01 =	4.0	5.9	36.4	0.5	0.3

and counts of the number of such heads was made on May 18, 1974 (Table XI). The number of white sterile heads was much larger in the early plots than in the late plots. Comparisons made among the 4 tillage levels revealed that there were larger numbers of white, sterile heads in tillage level 4 than in any of the other plots. There were no differences between the plots planted with treated seed and those planted with untreated seed. Also, isolations of H. sativum and Fusarium sp. were made from the underground portions of white, sterile head plants from early-planted plots (Table XII). The number of these pathogens isolated from crowns was much higher than from either the hypocotyls or root sections.

Tillage Level Study, 1974-1975

Crop Season

'Vitavax 200' - treated seeds of the cultivar 'Danne' and untreated seeds had a mean percentage germination of 81.6 and 82.2 respectively, in the laboratory.

The initial seedbed preparation for the 1974-1975 crop season was changed somewhat from the previous season. Although all tillage levels were handled as originally designed until planting time, it was decided after the 1973-1974 season, to loosen the soil in tillage levels 2 and 3 with a spring-tooth harrow before planting. This was done at the early planting date, but not at the late planting date, and the soil tended to repack in all plots between early and late seeding.

Consequently seeds were set at a normal depth at the early planting on September 30, but seeding was very difficult at the late

TABLE XI

A COMPARISON OF MEANS OF WHITE STERILE HEADS OF 'DANNE' BETWEEN 'EARLY' AND 'LATE' PLANTED PLOTS AND AMONG FOUR TILLAGE LEVELS DURING 1973-74 CROP SEASON

	Time of Planting	
TILLAGE LEVELS	Early	Late
1	40.1	1.6
2	37.4	2.4
3	48.1	3.9
4	61.5	6.8
LSD .01 =	13.0	4.0

TABLE XII

NUMBER OF ISOLATES OF HELMINTHOSPORIUM SATIVUM AND FUSARIUM SP. MADE FROM THREE PARTS OF PLANTS WITH WHITE, STERILE HEADS FROM EARLY-PLANTED PLOTS IN 1973-1974 CROP SEASON

H. sativum Isolates From:			*Fusarium* sp. Isolates From:		
10	10	10	10	10	10
Crowns	Hypocotyls	Root Sections	Crowns	Hypocotyls	Root Sections
1.8	0.9	0.7	3.1	0.6	2.9
LSD .01 = 1.0			LSD .01 = 1.2		

planting on November 15. Most of the seeds at the later date even in tillage levels 1 and 4, which were originally the best seedbeds, were scattered on or near the surface. Seeding was especially poor in tillage level 3. Fortunately, soil moisture was optimum.

Water erosion was a problem in the summer and early fall, particularly in tillage levels 1 and 4 (Figure 8).

Seedling emergence was recorded on early planting - date plots on October 11 and from late planting - date plots on December 16. No differences were detected nor was there a difference between treated and untreated plots. However, there was a significant difference in emergence between tillage levels (Table XIII). Again in the 1974-1975 season, tillage levels 1 and 4 were superior in almost all measurements to tillage levels 2 and 3.

A final stand count was made on April 6, 1975 and it was found that final stands were higher in late planted plots than in early planted plots (Table XIV), in spite of the planting difficulties encountered. Although the percentage of plants infected by H. sativum was higher in the early planted plots, the number of tillers per plant, foliage- and root-dry weight, yield and test wegiht were also higher in these early planted plots.

Isolations (Table XV) made from basal portions of leaf sheaths, hypocotyls and primary roots of plants from the early planting-date plots indicated that isolates of H. sativum were most frequent from tillage levels 1, 2, and 4 while isolates of Fusarium sp. were most frequent from tillage level 4. Most of the Fusarium sp. appeared to have come from the lower portions of the plants; the hypocotyl and primary roots (Table XVI). There were no differences between seed

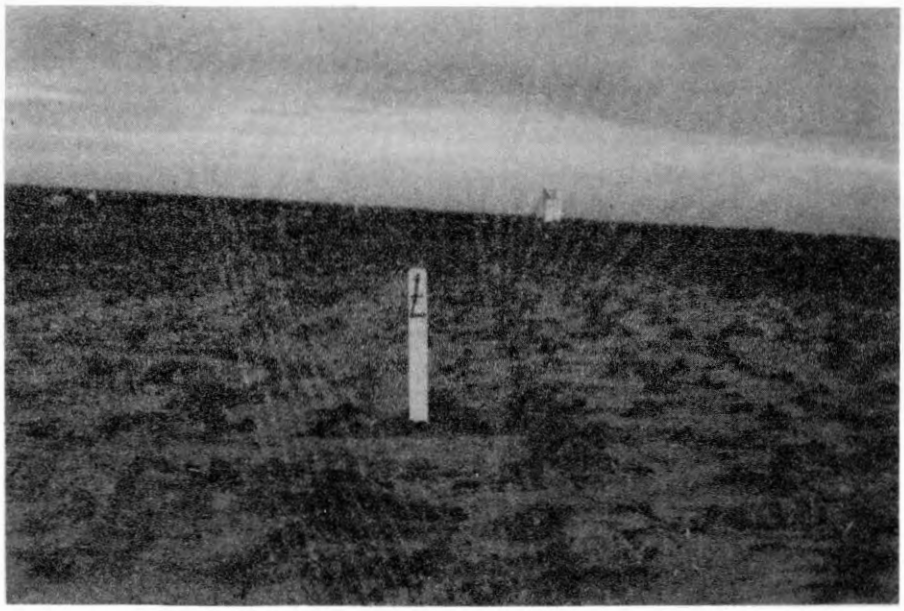

Figure 8. Water erosion in a plot of tillage level 1 (late planting date) in the fall of 1974.

TABLE XIII

A COMPARISON OF MEANS OF EMERGENCE, FINAL STAND, TILLERS PER PLANT, FOLIAGE-AND ROOT-DRY WEIGHT, YIELD AND TEST WEIGHT AMONG FOUR TILLAGE LEVELS IN 1974-1975 CROP SEASON

Tillage Level	Number of plants Emergence/m row	Final Stand	Tillers Per Plant	Foliage Weight in g	Root Weight in g	Grain Yield q/Ha	Test Weight Kg/Hl
1	41.9	44.5	5.3	6.2	1.0	20.8	76.1
2	34.1	36.7	3.9	4.1	0.6	20.6	75.8
3	35.7	40.9	4.6	4.6	0.6	18.7	74.3
4	41.8	42.3	5.5	7.0	0.9	22.2	76.1
LSD .01 =	4.8	5.8	1.1	1.1	0.2	2.5	1.7

TABLE XIV

A COMPARISON MEANS OF EARLY AND LATE PLANTING DATES FOR PERCENT OF PLANTS INFECTED WITH HELMINTHOSPORIUM SATIVUM, STAND, TILLERS PER PLANT, FOLIAGE AND ROOT-DRY WEIGHT, YIELD, AND TEST WEIGHT IN 1974-1975 CROP SEASON

	Percent of Plants Infected with *H. sativum*	Stand	Numbers of Tillers per Plant	Foliage Weight in g	Root Weight in g	Grain Yield q/ha	Test Weight Kg/Hl
DATE							
EARLY	17.9	38.9	5.6	7.1	1.0	26.0	76.5
LATE	4.7	43.3	4.0	3.9	0.5	15.2	74.6
LSD .01 =	7.7	3.2	0.5	0.7	0.2	1.7	1.2

TABLE XV

MEAN NUMBER OF ISOLATES HELMINTHOSPORIUM SATIVUM AND FUSARIUM SP. FROM WHEAT PLANT PARTS OF 10 PLANTS 47 DAYS AFTER PLANTING AT 4 TILLAGE LEVELS IN 1974-1975 CROP SEASON

Pathogen	Mean number of isolates from tillage levels				LSD	
	1	2	3	4	.01	.05
H. sativum	5.3	6.2	3.8	6.7	1.6	1.1
Fusarium sp.	1.1	1.0	0.9	1.7	0.4	

TABLE XVI

FUSARIUM SP. ISOLATES OBTAINED FROM VARIOUS PARTS OF 10 WHEAT PLANT PARTS 47 DAYS AFTER PLANTING IN 1974-1975 CROP SEASON

Wheat Parts	Basal Leaf	Hypo-cotyl	Primary Root
Fusarium sp. isolates	0.4	2.0	1.2

LSD .01 = 0.8

treated plots and untreated plots at either date.

Another examination (Table XVII) of all plots was made on April 12, 174 days after the early seeding. Although the percent of plants with hypocotyls over 0.5 cm in length, and the mean hypocotyl length was lowest in tillage level 3, the percent of hypocotyls infected with H. sativum was also highest at this tillage level. Number of tillers per plant was highest in tillage level 3 and 4 while foliage-and root-dry weight were highest in tillage levels 1 and 4.

Notes on the occurrence of white, sterile heads were taken on June 4, 1974 (Table XVIII). In the early-planted plots, mainly in tillage levels 2 and 3, white, sterile heads occurred in large patches and were almost too numerous to count. There were fewer numbers of white, sterile heads in plots planted with treated seed than plots planted with untreated seed.

Harvest for grain yield was done on June 29, 1975. Plots planted with treated seed gave higher grain yield than plots planted with untreated seed (Table XIX). Also, the early-planted plots yielded higher than the late-planted plots (Table XX). There was no difference in yield among the different tillage levels.

The percent of loose smutted heads per plot was counted on May 16, 1975. As expected Vitavax 200 at a rate of 2 gm/Kg totally controlled this disease (Table XXI), but there was also a significant difference in the percent of smutted heads between tillage level plots. Tillage level 3 had by far the least amount of smutted heads.

TABLE XVII

A COMPARISON OF TILLAGE LEVELS ON THE PERCENT OF PLANTS INFECTED WITH HELMINTHOSPORIUM SATIVUM, PERCENT OF PLANTS WITH HYPOCOTYLS OVER 0.5 CM., MEAN HYPOCOTYL LENGTH, NUMBER OF TILLERS PER PLANT AND FOLIAGE AND ROOT-DRY WEIGHT 174 DAYS AFTER PLANTING IN THE EARLY PLANTING-DATE PLOTS IN 1974-1975 CROP SEASON

Tillage Levels	Percent of Plants Infected with H. sativum	Percent of Plants with Hypocotyls Over 0.5 cm	Mean Hypocotyl Length in cm	Mean Number of Tillers/ Plant	Foliage Weight in g	Root Weight in g
1	27.4	76.0	2.7	12.2	25.2	4.3
2	39.6	71.1	2.7	12.9	22.6	3.7
3	31.9	39.4	1.8	13.9	24.3	3.7
4	24.3	80.0	2.1	13.4	29.2	4.9
LSD .01 =		39.9		1.4	4.5	0.8
LSD .05 =	11.6	27.8	0.7	1.0		0.5

TABLE XVIII

WHITE STERILE HEADS OBSERVED IN PLOTS PLANTED WITH SEED TREATED WITH VITAVAX-200 COMPARED WITH PLOTS PLANTED WITH UNTREATED SEED DURING 1974-1975 CROP SEASON

Treatment	Mean Number of White, Sterile Heads per Plot
Seed Treated with Vitavax-200	217.8
Control (Untreated)	262.1
LSD .05	37.7

TABLE XIX

A COMPARISON OF GRAIN YIELD FROM PLOTS PLANTED WITH SEED TREATED WITH VITAVAX-200 AND UNTREATED SEED IN 1974-1975 CROP SEASON

Treatment	Grain Yield q/Ha
Seed Treated with Vitavax-200	21.3
Control (Untreated)	19.9
LSD .01	1.3

TABLE XX

A COMPARISON OF GRAIN YIELD FROM PLOTS PLANTED EARLY AND LATE DURING THE 1974-1975 CROP SEASON

Date of planting	Yield q/ha
Early	26.0
Late	15.2

LSD .01 = 1.7

TABLE XXI

MEAN PERCENT OF LOOSE SMUTTED HEADS OF DANNE IN EACH OF THE FOUR TILLAGE LEVELS AND FROM PLOTS PLANTED WITH SEED TREATED WITH VITAVAX 200 AND UNTREATED SEED IN THE 1974-1975 CROP SEASON

Treatment	Percent of Loose Smutted Heads in Tillage Levels 1	2	3	4	Treatment $\bar{X}$	LSD
CONTROL (UNTREATED)	13.0	6.0	1.5	14.0	8.6	4.6
TREATED WITH VITAVAX 200	0	0	0	0	0	0
Tillage $\bar{X}$	6.5	3.0	0.8	7.0		

LSD .01 = 4.7

Tillage Level Study, 1975-1976

Crop Season

In contrast to previous seasons, 1975-1976 was dry. Seeding was not possible until late in October. Therefore, the early and late planting date plots were planted at the same time, on October 30, 1975. The incidence of the dry-land-foot-rot was considerably higher than in any other season during the course of this study.

Because of seeding depth difficulties in the previous crop seasons, particularly in tillage level 2 and 3, and because of the soil erosion problem by water and of a worsening situation with regard to weed control in tillage level 3, the entire study was moved and only 3 tillage levels were used. Because the newly-designed field plot for the 1975-76 crop season overlapped, at one corner, the old field plot where tillage level 3 had been, the weed problem remained severe at boot stage, it was decided to mow down the weeds and wheat in one entire replication to relieve that problem. Therefore, any data collected after the boot stage came from the 3 remaining replications.

Seedling emergence was measured on all plots on November 28, 1975. The data are presented in Table XXII. There were significant differences among tillage level plots, but no differences between seed-treated and untreated control plots. Tillage levels 1 and 3 had about the same emergence, but tillage level 2 was considerably less. On the same day, seedlings were brought to the laboratory, and the length of the hypocotyls was measured from the crown node to the old seed. This was also a relative measure of the depth of planting, which in turn was an indication of the level of seedbed preparation in each new

TABLE XXII

MEAN EMERGENCE AND SEEDLING DEPTH AND PERCENT OF SEEDLINGS OF DANNE INFECTED BY HELMINTHOSPORIUM SATIVUM IN THREE TILLAGE LEVELS IN 1975-1976 CROP SEASON

Tillage Levels	Emergence	Seeding Depth in Centimeters	Percent of Seedlings Infected with H. sativum
1	45.8	7.0	22.1
2	34.3	5.9	47.9
3	45.6	6.6	32.6
LSD .01 =	7.6	1.2	14.7

tillage level. It was found that tillage levels 1 and 3 had much longer hypocotyls, indicating a greater seeding depth and better seedbed than tillage level 2. At the same time isolations were made from coleoptiles, hypocotyls and primary roots of these seedlings. The percent of seedlings infected by H. sativum is presented also in Table XXII. This pathogen was isolated most often from the coleoptiles (Figure 9). There appeared to be no difference in the degree of infection among tillage levels. It should also be noted that no cultures of Fusarium sp. were isolated from the coleoptile at this stage of plant development.

On April 4, 1976, when plants were at boot stage, final stand, number of tillers per plant, percent of plants and hypocotyls infected by H. sativum, and foliage-and root-dry weight were determined. There were no differences between any of the plots in final stand, foliage- or root-dry weight, or number of isolates of H. sativum or Fusarium sp. Infection of the plants with H. sativum averaged 90 and 94%. All parts of the plant used for isolation were infected. Again it should be noted that less than 10% of the basal leaves were infected with Fusarium sp. compared to between 30 and 70% of the hypocotyls and roots.

On May 11, 1976, the percent of Helminthosporium leaf spot damage on flag leaves was recorded. Leaf spot damage on the flag leaf was as high as 50% of the leaf surface area, and up to 90% of the lower leaves (Figure 10). The percent of infected flag leaves is shown in Table XXIII. Tillage levels 1 and 3 were moderately infected while in tillage level 2 the infection was almost double that in the other tillage levels.

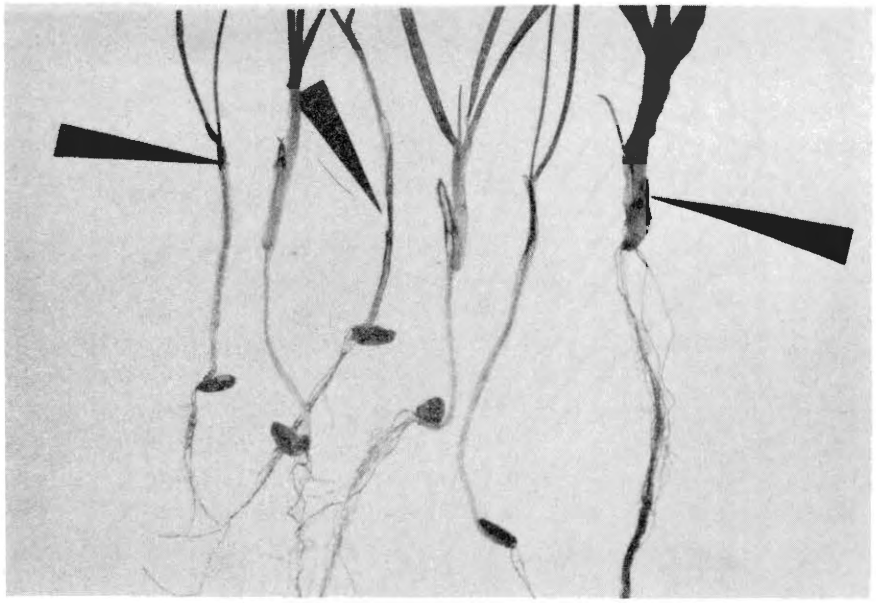

Figure 9. Wheat seedlings of the cultivar Danne 29 days after planting in 1975-76 crop season. Coleoptiles infected with *Helminthosporium sativum* are indicated by the black arrows.

Figure 10. Wheat leaves of the cultivar Danne infected by Helminthosporium sativum during the flowering stage in 1975-76 crop season.

TABLE XXIII

PERCENT OF FLAG LEAVES OF DANNE INFECTED BY HELMINTHOSPORIUM SATIVUM IN EACH OF THREE TILLAGE LEVELS IN 1975-1976 CROP SEASON

	Tillage Levels		
	1	2	3
Percent flag leaves infected by H. sativum	37.3	60.7	40.0

LSD .01 = 17.3

Finally, on June 3, 1976, general appearance and uniformity of field plant stand was rated as acceptable, fair, and unacceptable. The high incidence (Table XXVI) of white, sterile heads made it difficult to count individuals and therefore, this disease symptom was rated on a scale of 0 to 9 where 0 = no disease, 1, 2, and 3 = low disease incidence, 4, 5 and 6 = moderate incidence and 7, 8 and 9 = severe incidence (40). It was found that tillage levels 2 and 3 rated higher than tillage level 1.

The abundance and excessive growth of weeds prevented harvesting the plots for grain yield (Figure 11).

TABLE XXIV

OCCURRENCE OF WHITE, STERILE HEADS IN THREE TILLAGE LEVELS IN 1975-1976 CROP SEASON

Tillage Levels	Rating of numbers of White, Sterile Heads 0 = None 9 = Most
1	5.2
2	8.5
3	8.0
LSD .01	2.3

Figure 11. Cheatgrass and broad leaf weed infested plot of tillage level 3 in the early-planted plot during 1975-76 crop season.

CHAPTER V

DISCUSSION

Some form of minimum-or stubble-mulch tillage is the obvious solution to water conservation and wind and water erosion in the central great plains area of the United States, and perhaps in similar dry-land farming areas in the rest of the world. Some other significant problems come with the benefits, however. The field studies reported here definitely indicated that seedling blight and root-rot problems are pronounced in minimum tillage systems.

Since root-and foot-rot infections often start with infected seedlings, one obvious control method would be the practice of treating seeds with a fungicide. Consequently, a number of fungicides used at various rates were tested in the field at 2 locations in 2 different years. The results indicated that seed treatment may be effective in controlling root-and foot-rots, and thereby increasing yield, but it can not be expected to accomplish the desired result each year in all areas. In this study, several fungicides reduced seedling infection by H. sativum, but in only 1 case was this reflected in improved grain yields. Such results are probably to be expected, however, particularly with winter wheat where the protection of the plant by the treatment could be expected to last at best a few weeks for a plant that is in the ground nearly 9 months from planting to harvest. The degree of yield increase might then be expected to relate

to the time of optimum infection by the causal agents.

Another control measure often recommended for root-and foot-rot control is rotation, which may have the effect of introducing competitive organisms into the soil complex and of diluting the level of inoculum of the pathogens. The study made in the growth chamber and reported here was partly concerned with these effects. When inoculum of Fusarium sp., itself a pathogen of wheat was mixed in equal portions with inoculum of H. sativum infection of wheat seedlings by the latter was significantly reduced - but not by half. The results would indicate a dilution factor more than competition.

In various field tests in Oklahoma, particularly in disease monitoring plots, the cultivar Aniversario has shown more root-and foot-rot than other cultivars in these tests. This cultivar, together with the widely grown cultivar Danne, was used in the growth chamber to test its response to infection by H. sativum and Fusarium sp. Unexpectedly, Aniversario had less infection by either pathogen than Danne. This might indicate that some other pathogen is responsible for the behavior of Aniversario in field plots. It also indicated, however, that there are differences among cultivars in their response to H. sativum and Fusarium sp. and that resistance to these pathogens may be available.

Another factor that has apparantly contributed to the root-rot problem is the practice of planting early, before soil temperatures are optimum for wheat, to obtain earlier foliage for livestock grazing. The field experiments reported here incorporated tillage levels with early planting to study the effect of these factors on various disease and yield characteristics. In both years where early and late

planting could be compared there was more foliar, and root growth, and grain yield in the early plots than in the late. It should be mentioned, however, that no plantings in this study were made before September 22, which is not very early by planting standards in the area where these studies were made. It was also found that these higher grain yields were obtained in spite of a higher incidence of white, sterile heads in the early planted plots, and a higher level of infection by H. sativum in seedling plant parts.

Tillage level 1, clean plowed, provided plants with less seedling infection by H. sativum, less incidence of white, sterile heads, and greater yield in all catagories of measurements including grain yield than any of the other tillage systems used. However, as indicated before, the seedbed in the other tillage systems was very rough and difficult to plant. It may be, therefore, that the superiority of clean plowing may be due, at least in part, to a superior seedbed producing a more vigorous and healthy seedling. This point is certainly worth further investigation.

Several other interesting points were observed in these field studies. One was that few other organisms were obtained in isolations from seedling plant parts (Figure 5). Since Rhizoctonia solani is almost omni-present in soils in Oklahoma and has been isolated from diseased wheat seedlings, it was expected that this fungus would be found in these studies. It occurred only rarely, but it is also possible that the methods used in isolation excluded it. Also, colonies of H. sativum are limited by, and distinct from other colinies in the same petri dish. Other fungi, such as Fusarium sp. may grow with or over H. sativum colonies but 2 colonies of H. sativum seldom

arise from 1 diseased plant part, and if this does occur these colonies remain distinct.

It was noted in at least 2 years of the study that isolates of Fusarium sp. were seldom obtained from plant parts near the surface of the soil in the seedling stage. Coleoptiles, for example, basal portions of primary leaves and upper portions of hypocotyls and secondary roots seldom yielded isolates of Fusarium sp. while these same areas had been invaded by H. sativum. Both of these fungi could often be found in diseased crown tissues of plants with white, sterile heads, but this was late in the season at the pre-ripening stage of plant development.

It also was of interest that tillage levels 1 and 4 had significantly more loose smut even though they were planted at the same time from the same seed lot. It is possible this also has to do with the type and rapidity of seedling growth. Again, it warrants further investigation.

Finally, there was no significant interaction between planting date and tillage level in any of the various characteristics that were measured. It is apparent that these 2 phenomena influence disease development and plant growth independently.

CHAPTER VI

SUMMARY

1. In 1972-73 twenty nine chemical-rate combinations were tested as seed treatments on wheat and barley. None produced better stands or higher yields than the controls. Several treatments had significantly less emergence and yield than the untreated control. A similar test in 1973-74 indicated that one treatment, M3854 was promising, and that Vitavax 200, LT2 plus Zinc Omadine, and L205 plus Zinc Omadine, each gave control of loose smut of barley. Treatment Vitavax resulted in significantly higher grain yield in the barley plots.

2. In growth chamber studies, H. sativum, alone, produced higher disease severity than when it was complexed with Fusarium sp. On the other hand, the latter produced only minor disease symptoms but was consistently reisolated.

3. Of the 2 cultivars investigated Aniversario was found more resistant than Danne.

4. Colonies of H. sativum remained distinct in culture where those of Fusarium sp. did not.

5. In 2 consecutive crop seasons between 1973 and 1975, tillage levels 2 and 3 were found hard to manage. Seedbeds were rough, trashy and hard-packed. Volunteer winter wheat on tillage level 2 and an excessively high incidence of cheatgrass, Bromus secalinus L., at both tillage levels 2 and 3 were high priority problems.

6. Wheat plants from tillage levels 2 and 3 resulted in very short hypocotyls, presenting a significantly smaller area available for infection by seedling pathogens entering this organ.

7. Emergence, dry-foliage weight, dry-root weight, and grain yield were all higher for early planted plots than for late planted plots.

8. Emergence, final stand, dry-foliage weight, dry-root weight and grain yield were all higher for tillage levels 1 and 4 than for tillage levels 2 and 3.

9. Early planted plots had a higher level of white, sterile heads (root-rotted plants) than late planted plots. Tillage level 4 had a higher incidence of white, sterile heads than the other tillage levels.

10. H. sativum was isolated more from the crowns of the plants with white, sterile heads than from the hypocotyls or roots, but Fusarium sp. isolated came about equally from the crown and roots with fewer isolates from the hypocotyls.

11. Vitavax 200 treated seed was found effective in increasing the number of tillers per plant, loose smut control, fewer incidence of white, sterile heads, and increased grain yield in the 1974-1975 crop season.

12. Tillage levels 1 and 4 had better emergence, stand, tillering, foliage and root weight, grain yield, and test weight than tillage levels 2 and 3.

13. Tillage levels 1 and 4 also had the highest number of plants with hypocotyls over 0.5 cm in length, but in spite of this had the lowest percent of infection with H. sativum.

14. Isolates of Fusarium sp. were obtained more often from

hypocotyls and primary roots than from coleoptiles or upper portions of hypocotyls in the 1974-75 season.

15. Although early planted plots had the poorest stands and produced the greatest percent of plants infected with H. sativum they again had the best tillering, highest foliage and root weights, best grain yield, and grain test weight in the 1974-75 season.

16. When untreated seed was used loose smut was greatest in tillage levels 1 and 4 and least in tillage level 3.

17. In 1975-76, a much drier season, tillage level 2 had the poorest emergence, shortest hypocotyls, and the highest percent of infected seedlings and the highest percent of leaves infected with H. sativum.

18. There were more white, sterile heads in 1975-76 than in previous wetter seasons, and tillage levels 2 and 3 had far more than tillage level 1.

19. Weeds, particularly Bromus secalinus L., were more numerous in 1975-76 than in previous seasons.

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